

NATIONAL BUREAU OF STANDARDS

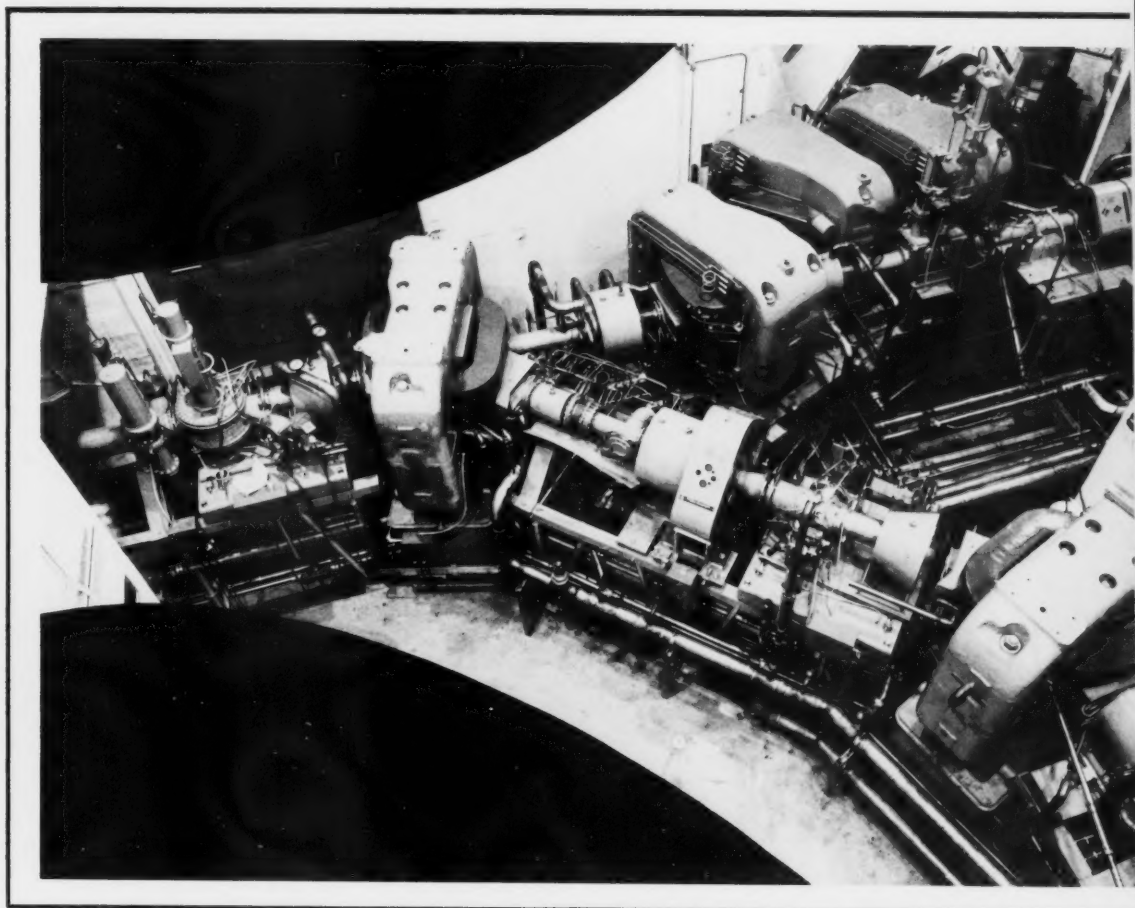
January 1967

Technical News Bulletin

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TECHNOLOGY & SCIENCE



U.S. DEPARTMENT OF COMMERCE

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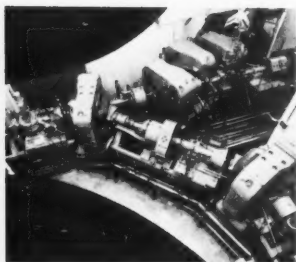
NATIONAL BUREAU OF STANDARDS

Technical News Bulletin

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COVER

NBS linac magnet room. In this room a system of magnets and collimators refines the energy spread of the linac beam, which comes from the left, to less than 0.1 percent and steers it into one of three measurement rooms.



U.S. DEPARTMENT OF COMMERCE

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NATIONAL BUREAU OF STANDARDS

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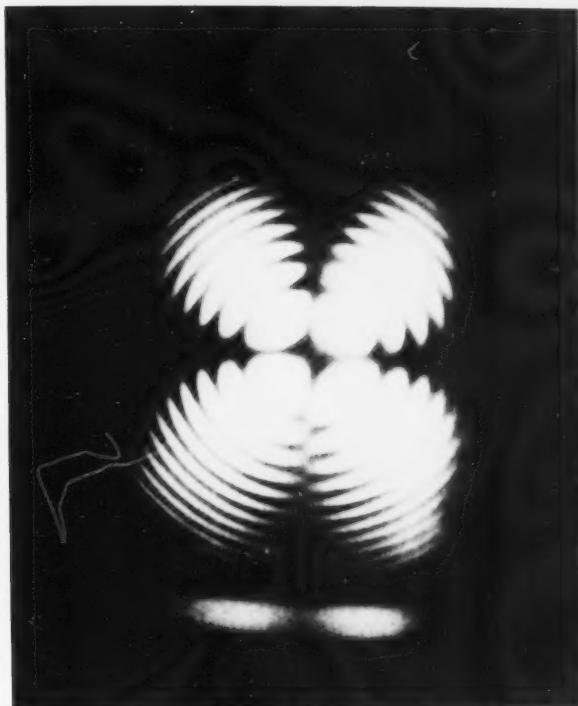
The National Bureau of Standards serves as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. For this purpose, the Bureau is organized into three institutes—
• The Institute for Basic Standards
• The Institute for Materials Research
• The Institute for Applied Technology
The TECHNICAL NEWS BULLETIN is published to keep science and industry informed regarding the technical programs, accomplishments, and activities of all three institutes.

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TECHNOLOGY & SCIENCE

A view of an ice crystal in a convergent light polariscope. The orientation of the crystal lattice Z-axis with respect to the surface normal is being determined. The dark cross marks the position of the Z-axis.



Elasticity of Ice

Although extensive research has been conducted on the elasticity of ice in the temperature range from 273 down to 240 °K, very little is known of this property of ice below these temperatures. A study of ice at these low temperatures, in addition to increasing the general knowledge of its properties, may benefit future space explorations that will encounter these temperatures. Studies of the thermodynamic properties of ice may also give the physical chemist a better understanding of hydrogen bonding, as ice is one of the simplest lattices in which hydrogen is found.

Recently T. M. Proctor of the Institute for Basic Standards measured the speed of sound in single-crystal ice from 250 to 40 °K.¹ This study, supported by the Office of Naval Research, was to determine the elasticity of ice. Elasticity, which is

directly related to the speed of sound, determines to a great extent the mechanical properties of a material.

Speed of Sound

The study was made by measuring the transit time of a high-frequency ultrasonic pulse across 2.54-thick ice crystals. This was accomplished by generating two sharp 50-volt spikes less than 0.05 microsecond long. A counter measured the frequency of the pulses and thereby the time interval between them. After the generation of the two pulses there was a dead time of 255 periods; the sequence was then repeated.

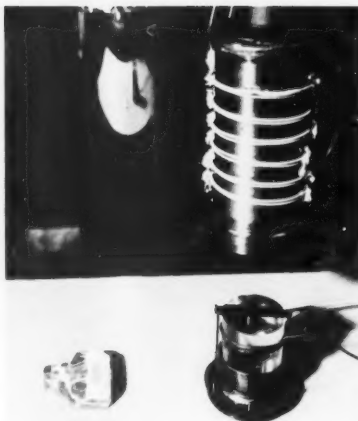
The two pulses excited a barium titanate transducer, attached to the ice sample by a bonding agent, generating two families of acoustical reflections. The acoustical pulses traveled across the crystal, where they were reflected

by the crystal surface, and returned to the transducer. These signals were then picked up by the transducer, amplified, and sent to an oscilloscope that was used for setting coincidences between families of pulses.

Coincidences were set by varying the frequency so as to match the first half cycle of the second reflection generated by the first electrical pulse to the first half cycle of the first reflection produced by the second electrical pulse. This coincidence represents the summation of one pulse that has traveled across the crystal and returned and one pulse that has twice crossed and returned. As the counter measured this frequency, the time required for a pulse to travel across the crystal and return was known. The speed of sound was then calculated from this time and the known distance across the crystal.

continued

Left: The sample container used to determine the elasticity of ice is shown disassembled. A specimen of fused silica glass (lower right) has been inserted in place of an ice crystal to demonstrate the apparatus at room temperature. Heater windings around the container (upper right) control the temperature of the specimen. A transducer attached to the specimen generates sound waves for speed measurements. An unshaped ice crystal (lower left) is representative of those used in the experiments. Right: T. M. Proctor examines a partially grown ice crystal. The elasticity of ice was determined by measuring the speed of sound in ice crystals grown in this apparatus.



ELASTICITY OF ICE *continued*

Ice Crystals

The ice crystals used in the NBS study were grown from a seed frozen to the end of a copper-rod heat sink. The other end of the rod was attached to a container of dry ice and acetone. The seed crystal was held at the top of a melt of degassed, distilled water. This melt was completely surrounded by a mixture of ice and water so that the temperature of the melt was kept very near freezing. As heat was drawn up through the rod, the temperature of the ice crystal was reduced. Surface water was then drawn down across the crystal by a stirring process so that water froze on the crystal causing it to grow. Growth of the crystal was confined by two parallel plates spaced 2.54 cm apart. Rate of growth was also controlled to 3 to 4 mm per hour by a heating collar around the rod.

The resulting crystals are completely transparent and have no visible inclusions or bubbles. To insure that the ice crystals are single they were carefully examined for grain boundaries in a polariscope.

Low Temperatures

The low temperatures were ob-

tained by using a standard Dewar system, a stainless steel container, and a copper container. The copper container held the ice sample, transducer, and the electrical leads for the transducer and a thermocouple attached to the ice sample. The copper sample holder was located inside the vacuum-tight stainless steel container. The stainless steel container was then immersed in a liquid nitrogen bath held by the Dewar. Heater windings around the copper container allowed regulation of the temperature.

Elasticity

As ice is an anisotropic material (hexagonal crystal), five independent ultrasonic experiments had to be performed using longitudinal and shear waves propagated along three different directions through the crystal. From these speed-of-sound measurements, the five independent elastic constants of ice were computed. This computation involves solving five simultaneous equations which relate the five measured sound speeds to the five independent elastic constants.

To determine the elastic constants as a function of temperature, the above mentioned computations were completed for many sets of velocity data taken at different temperatures. The results were fitted by the method

of least squares to second-degree polynomials of the form

$$C_{ij} = A_0 + A_1T + A_2T^2$$

where C_{ij} is the elastic constant and T is the temperature. Five sets of coefficients were determined for the five independent elastic constants C_{11} , C_{33} , C_{44} , C_{12} , and C_{13} .

The results indicate that the precision of these measurements is within 500 parts per million for longitudinal measurements and within 1000 ppm for shear measurements. Approximately 300 ppm of the uncertainty is in the ice crystal dimensions.

The accuracy of the method was checked by measuring the speed of sound in a set of aluminum gage blocks. As the density and geometry were well known in the aluminum blocks, most errors due to time delay in the bond between transducer and sample would be detectable in such a speed-versus-path length experiment. This comparison showed that time-delay errors were less than 0.1 percent.

¹ For further technical details, see Low temperature speed of sound in single-crystal ice, by T. M. Proctor, J. Acoust. Soc., 39 (May 1966).

Instruments for measuring alternating voltages can be compared with known a-c or d-c references by means of a peak alternating voltage comparator developed at the National Bureau of Standards by Louis Marzetta and Donald Flach.¹ It is now used in making peak voltage comparisons at spot frequencies between 50 and 2400 Hz with an accuracy conservatively believed to be 100 ppm. This accuracy is needed to match the present validity of rms (root-mean-square) values computed from peak measurements, resulting from the waveform purity of today's a-c references, in comparisons for evaluating rms-measuring instruments.

Measurements of Alternating Voltages

Accuracies obtainable in measuring alternating voltages have historically lagged behind those for direct voltage measurements, in part because the fundamental standards of voltage and current are for direct current. In addition, the terms in which alternating current and voltage are expressed (average, peak, and rms values) have simple relationships only for perfectly sinusoidal waveforms.

Alternating voltages are commonly expressed as rms values (proportional to the square root of the sum of the squares of instantaneous values),² even when obtained from averaging circuits which give correct values only for sinusoidal waveforms. Peak values can be computed from rms values of sine waves, but computation of peaks of nonsinusoidal waveforms requires use of detailed waveform analysis.

Recently peak-measuring meters have appeared in laboratories and been presented at the Bureau for certification. The Bureau's electronic instrumentation laboratory was asked to design a comparator for certifying these instruments directly, and also for comparison of peak values with values obtained from rms measurements.³

Design of the Comparator

The NBS peak comparator uses two synchronously driven relays to sample the peak of the a-c input for direct comparison with a d-c voltage from a precision source adjustable to six figures. The relays are mercury-wetted, reed relays which have low contact bounce and are capable of high-speed operation.

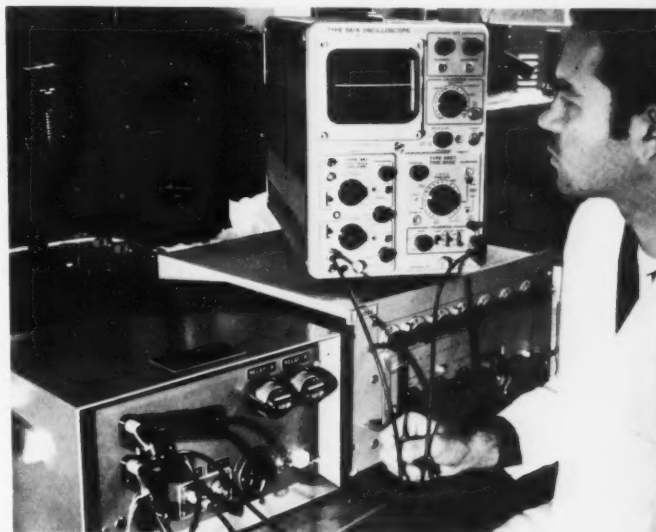
The relays are driven by amplifiers which receive their inputs from relay synchronizing circuitry. This has as its input the a-c signal being compared, which it divides in frequency (by a factor adjustable from 1 to 64) to obtain a synchronizing signal close to 50 Hz. The synchronizing signal triggers a series of multivibrators performing functions of time delay and gating, the ultimate output of which controls the two relay amplifiers.

Use of the Comparator

The calibrated d-c input is connected to the detection circuitry both while the relays are energized and while
(continued on p. 15)

Peak A-C, D-C Voltage Comparator

Donald Flach watches the oscilloscope indication as he adjusts a d-c input to the NBS peak voltage comparator (left) to equal peaks of the unknown alternating voltage.



Errors Determined for Ellipsometry Measurements

Because of the importance of ellipsometry for measuring the optical constants of metallic surfaces, an evaluation of the technique has been made recently at the NBS Institute for Materials Research. In research supported by the U.S. Army Research Office (Durham, N.C.), L. E. Smith and R. R. Stromberg have determined the optical constants of mercury with an ellipsometer and have used the results to assess the errors inherent in the method and the instrument.¹ Detailed knowledge of these errors can be a valuable aid to those fields of surface physics and chemistry which use the ellipsometer to obtain surface property data.

The ellipsometer makes use of the change in the state of polarization of light upon reflection from a surface from which the optical constants of the surface can be determined. The range of values obtained for the optical constants of various metals, however, is larger than can be expected from a consideration of the precision of the instrument alone. This NBS study calculates the magnitude of errors arising from such probable sources as surface films and misalignment of the instrument.

In the present study the optical constants (components of the refractive index) of mercury were measured at 5461 Å with three different liquids—water, cyclohexane, and benzene—in contact with the mercury surface. The mercury was purified by vacuum distillation and gases were removed from the other liquids by boiling before each experiment. After purification the mercury was covered by the liquid without being exposed to air to prevent formation of any thin films on the surface of the mercury. Previous workers had made measurements² using glass, vacuum, nitrogen, or air in contact with the mercury surface.

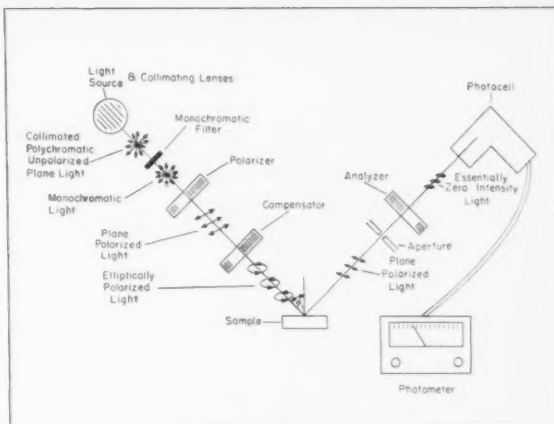
To estimate the effect of these different experimental arrangements, calculations were made, therefore, of the magnitude of errors in the observed refractive index that could arise for several hypothetical surface films formed under three contact media: air, glass, and cyclohexane. The hypothetical surface films were air, oil, and a weakly absorbing oxide-like material with a refractive index near that of mercury. In general, the calculations, which were made for two thicknesses of films (2 and 10 Å), showed that a very thin film of air on the mercury surface would cause an appreciable error in the measured index of refraction under each of the three contact media. However, surface films with an index of refraction only slightly different from that of mercury were shown not to change significantly the measured optical constants of mercury except at the larger thickness.

Misalignment of the polarizing prisms of the ellipsometer was found to be the other major source of error in measuring optical constants and was shown to have one especially important consequence: an apparent dependence of the optical constants on the angle of incidence of the polarized light beam. Previous measurements had shown such an angular dependence although it was not

predicted theoretically and thus was not expected by the scientists who observed it experimentally. The results of the present investigation, however, indicate that the apparent angular dependence was merely a consequence of the misalignment of the prisms in the ellipsometer.

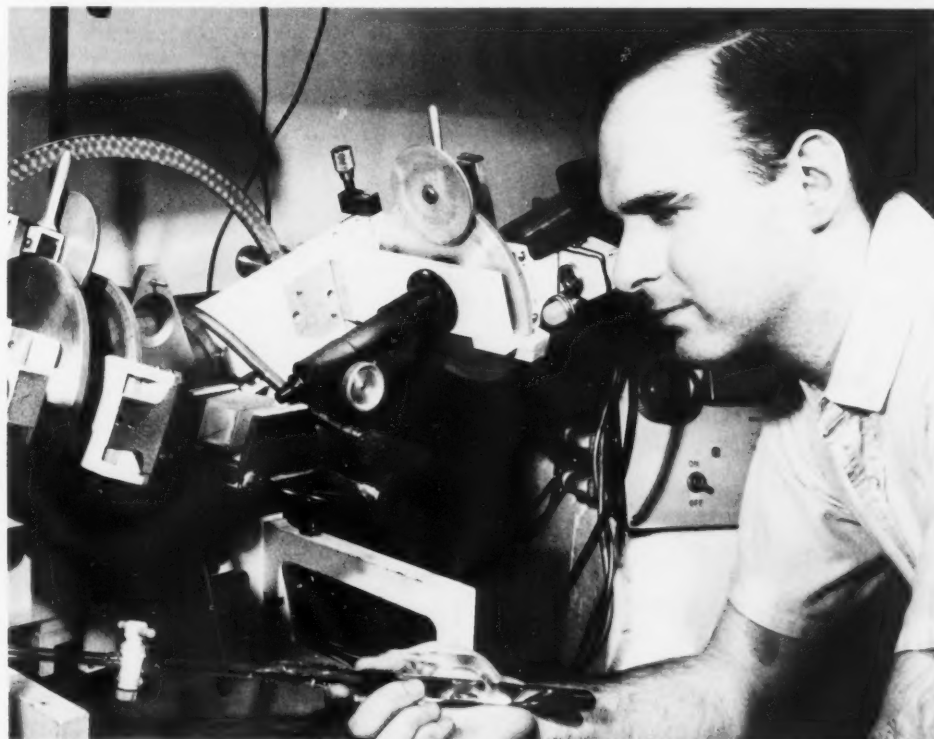
For further technical details, see Measurement of optical constants of liquid mercury at 5461 Å, by L. E. Smith and R. R. Stromberg, J. Opt. Soc. Am. (Nov. 1966).

Determination of the dispersion and absorption of metals for the visual and ultraviolet spectrum, by W. Meier, Ann. Physik 31, 1017 (1910); An optical examination of thin films: I. The optical constants of mercury, by L. Tronstad and C. G. P. Feachem, Proc. Roy. Soc. (London) A145, 115 (1934); The polarimetric determination of optical properties, by R. M. Emberson, J. Opt. Soc. Am. 26, 443 (1936); Experimental study of the optical properties of liquid mercury and liquid gallium in the wavelength range of 0.23 microns to 13 microns, by L. G. Schultz, J. Opt. Am. 47, 64 (1957); Optical properties of liquid mercury and gallium in the visible and near infrared regions of the spectrum, by L. G. Lelyuk, I. N. Shklyarevskii, and R. G. Yarovaya, Opt. i Spektroskopiya 16, 484 (1964); and Measurement of the optical constants of mercury and mercury-indium amalgams in the spectral region 4000–17000 cm^{-1} , by J. N. Hodgson, Phil. Mag. 4, 183 (1959).

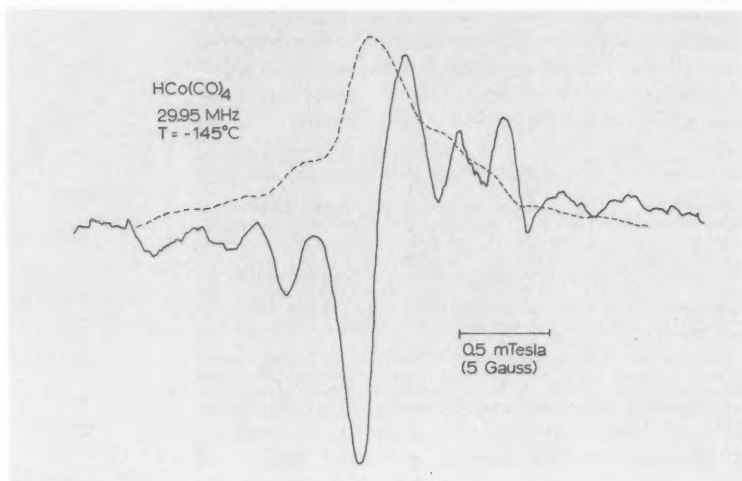


Schematic drawing of the ellipsometer. In this instrument with the components arranged as shown, polarized light is adjusted to the proper ellipticity so that upon reflection it is converted into plane polarized light which then may be extinguished by the analyzer. The state of polarization is determined from the angular readings of the components.

NBS chemist L. E. Smith (in front of the ellipsometer) is holding a "break-tube" in which uncontaminated mercury is prepared under a liquid. He will decant (by breaking the seal of the tube) some of the mercury under liquid into the liquid cell-holder shown at the center of the ellipsometer.



Proton magnetic resonance spectrum of $\text{HCo}(\text{CO})_4$. The solid curve is the derivative spectrum as recorded; the dashed line is the absorption spectrum calculated therefrom. Spectrometer frequency: 29.95 MHz; $T = -145^\circ\text{C}$; Modulation amplitude: 1.5 gauss; Modulation frequency: 200 Hz.



Molecular Bond Distances Determined by NMR

Studies of transition element-hydrogen compounds are now being conducted at the NBS Institute for Materials Research. The studies are providing important new insights into the molecular structure of such materials. In these studies, T. C. Farrar is using broad-line nuclear magnetic resonance (nmr) to determine metal-hydrogen bond distances, and to obtain information about molecular motion in manganese pentacarbonyl hydride $[\text{HMn}(\text{CO})_5]$,¹ cobalt tetracarbonyl hydride $[\text{HCo}(\text{CO})_4]$,² and related compounds.

The carbonyl hydride work is part of a general program of nmr study involving inorganic compounds. The objectives of this NBS program are to study the molecular and electronic structure of a variety of inorganic materials and to investigate the theoretical and experimental aspects of nmr methods by measurements on carefully selected model compounds.

The nature of the metal-hydrogen bond in the metal carbonyl hydrides is of considerable interest, both theoretical and practical, because of the possible significance of these materials in catalysis. Although some carbonyl hydrides have been known since the 1940's, the bonding between hydrogen and the transition metal atom has been poorly understood owing to the absence of direct experimental evidence on bond lengths and molecular geometry.

The lack of experimental data on these bond lengths has been caused by a combination of circumstances. The hydrogen atoms in solids are difficult to locate accurately by x-ray methods, particularly in the presence of heavy atoms. In principle, this problem could be overcome by combining single-crystal x-ray and neutron diffraction studies. Unfortunately, however, such a combination is not always possible. Also many of the compounds of the greatest theoretical interest are thermally unstable. Cobalt carbonyl hydride, for example, is an unstable liquid which decomposes at its melting point (-26°C). Single crystals of the pure material consequently are difficult to obtain.

To account for the results of certain spectroscopic experiments, some workers proposed that the hydrogen atom in the carbonyl hydride lies very close ($1.1\text{--}1.2 \text{ \AA}$ [$0.11\text{--}0.12 \text{ nm}$]) to the central metal atom and that it does not occupy a definite position in the coordination sphere. In recent years, more stable materials containing transition metal-hydrogen bonds have become available. Crystal structure studies on these have indicated that the hydride ligand probably lies in a distinct geometrical position in the arrangement of ligands about the metal atom. Some experimental results have also suggested that the metal-hydrogen bond distances are in fact in the

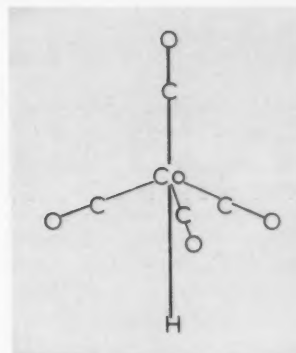
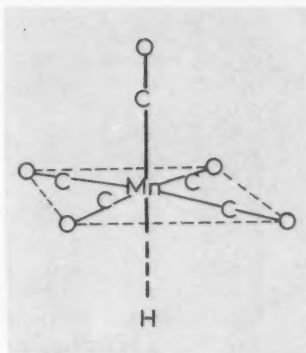
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neighborhood of 1.6 Å (0.16 nm), but the difficulties already mentioned have prevented any direct measurements of these distances.

Broad-line nmr measurement offers a powerful method for locating hydrogen in solids that are polycrystalline. The second moment of the resonance curves may be used to determine internuclear distances when other details of the crystal structure are known. In some cases additional information may be obtained from the nmr spectrum, that makes it possible to determine hydrogen atom positions on the basis of the nmr spectrum alone.

For $\text{HMn}(\text{CO})_5$, the positions of all the heavy atoms in the crystal are known from x-ray studies.³ For $\text{HCo}(\text{CO})_4$, the analysis of the nmr spectrum shows that the cobalt-hydrogen distance may be determined without knowledge of the positions of the carbonyl groups or of the molecular arrangement in the unit cell. Work at NBS has provided the first experimental location of hydrogen in this class of compounds by showing that the metal-hydrogen distances in $\text{HMn}(\text{CO})_5$ and $\text{HCo}(\text{CO})_4$ are in the neighborhood of 1.3 Å (0.13 nm).

This work has been made possible by close cooperation between Dr. Farrar and Dr. F. E. Brinckman, J. Cooper, and Dr. T. D. Coyle, the NBS chemists who prepared the compounds used in these studies. In some cases, highly unstable compounds like cobalt and iron hydride derivations have been prepared and nmr spectra have been obtained on the same day. For other, more stable compounds, samples prepared by collaborators in university laboratories have also been used. The nmr technique is particularly well suited to structural studies of hydrides, but can also be applied to a wide range of compounds of fluorine, boron, phosphorus, nitrogen, and other elements.



Above left: The molecular structure of the heavy atoms of manganese pentacarbonyl hydride is known from x-ray studies. The hydrogen atom probably occupies one vertex of an octahedron. Above right: A possible molecular structure for $\text{HCo}(\text{CO})_4$.

For example, these same techniques were used to measure the boron-hydrogen distance in dimethoxyborane, using specially-prepared isotopic samples containing essentially pure boron-11 and fully deuterated methyl groups.¹

¹ Manganese-hydrogen bond distance in $\text{HMn}(\text{CO})_5$, by T. C. Farrar, W. Ryan, A. Davison, and J. W. Faller, *J. Amer. Chem. Soc.* **88**, 184 (1966).

² A broad-line proton magnetic resonance study of cobalt tetracarbonyl hydride, by T. C. Farrar, F. E. Brinckman, T. D. Coyle, A. Davison, and J. W. Faller (to be published).

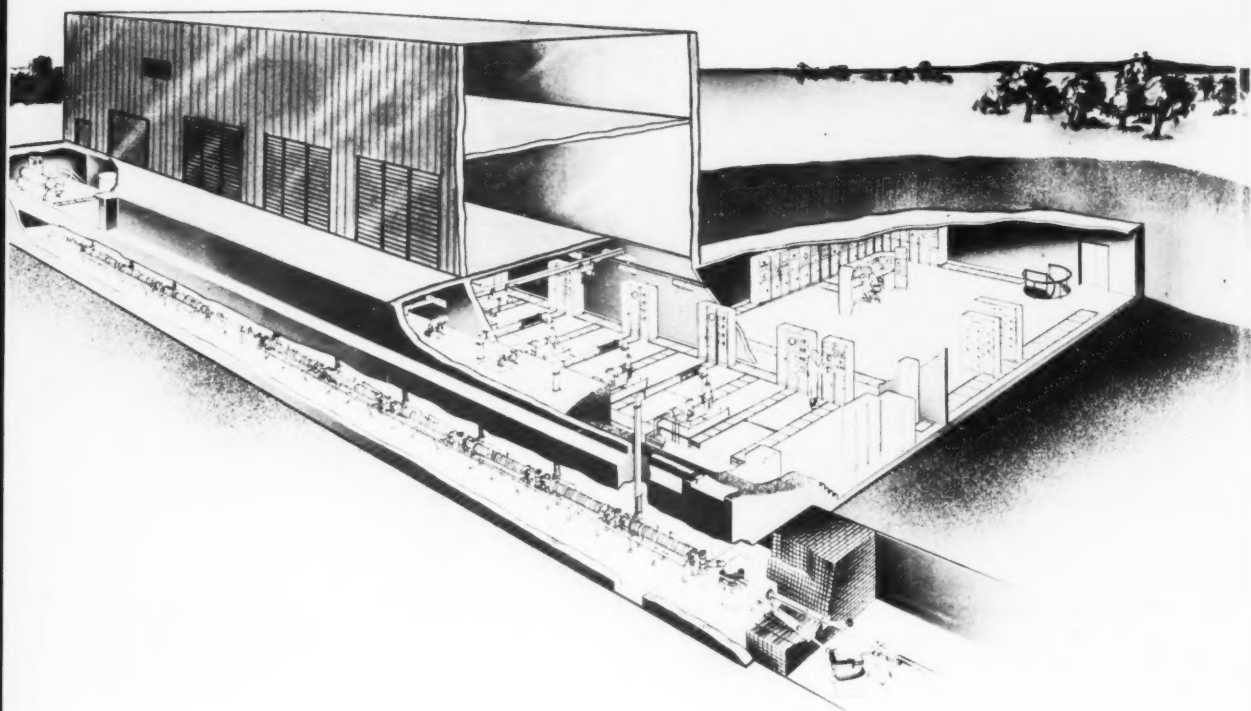
³ Crystal and molecular structure of manganese pentacarbonyl hydride, by S. J. LaPlaca, W. C. Hamilton, and J. A. Ibers, *Inorg. Chem.* **3**, 1491 (1964).

⁴ Proton broad-line NMR study of dimethoxy-d₅-borane-¹¹B, by T. C. Farrar, J. Cooper, and T. D. Coyle, *Chem. Comm.* (in press).

APPLIED OPTICS FEATURES NBS

In commemoration of the dedication of the Bureau's Gaithersburg (Md.) laboratories on November 15, the January 1967 issue of *Applied Optics* will feature the work of the National Bureau of Standards in optics and related fields. A color photograph of the new NBS site will appear on the cover. Serving as co-editors for this special issue will be Dr. Karl G. Kessler, Chief, NBS Atomic

Physics Division, and Dr. Irvine C. Gardner, who was Chief of the NBS Optics and Metrology Division until his retirement in 1959. Included in the January contents will be 19 papers by present and former members of the NBS staff. Single copies of the issue may be obtained for \$3 from the American Institute of Physics, 335 East 45th Street, New York, N.Y. 10017.



Stray radiation from the NBS linear accelerator is minimized by placing the high-radiation area underground, as shown in this cutaway view.

NBS Linear Accelerator Goes Into Operation

Intense Beam Gives High Dose Rate

A new linear particle accelerator, or linac, that produces one of the world's most intense electron beams has been placed in operation at the National Bureau of Standards' new laboratory complex at Gaithersburg, Md. With an electron power output of more than 80 kW—an intensity 200,000 times greater than previously available at the Bureau—this beam can produce extremely high radiation dose rates in materials of all kinds.

The NBS linac's well-defined beam, highly stable and extremely small in energy spread, can be controlled by magnetic fields and made to interact directly with various materials, or it can be directed at certain targets to generate other radiations, such as x rays, positrons, or neutrons. Its electron energies are continuously variable from 10 to 150 MeV. The new accelerator thus provides a powerful, flexible, and versatile tool which the NBS Institute for Basic Standards can use to develop the measurement science now urgently required because of recent advances in electron-beam technology.

Within the last 5 years, applications of electron beams have been revolutionized by improvements in methods for the production and detection of high-energy electrons. In physics, chemistry, biology, and related sciences, electron

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beam applications are expanding as rapidly as accurate, reproducible methods can be developed for defining and measuring electron beams. In nuclear physics, for example, the generation of stable, well-resolved beams of electrons brings the possibility of obtaining unique nuclear data with electrons. In atomic physics, the production of intense vacuum-ultraviolet and far-infrared radiation in electron accelerators offers new research techniques for exploring atomic structure. For the radiation chemist, the controllable generation of very-short-duration, high-intensity electron pulses opens up a new world of reaction rate chemistry. And finally, for the industrial and medical processor, the economic production of controllable high-intensity electron beams means a whole new dimension in the processing of materials—the sterilization of food and pharmaceuticals, the refining and deposition of refractory metals, and the production of new types of plastics.

All such uses of intense high-energy electron beams require that the specific radiation effects they produce be carefully monitored and controlled. In industrial applications thousands of measurements must be made daily. Accurate, reproducible measurements are thus required to characterize the electron fields under actual conditions of use as well as the radiation effects produced by exposure of materials in these fields. Thus there is a great need to develop a measurement science that can define, measure, and control electron beams and their radiation effects reproducibly and accurately. In this effort the NBS linac will play an important role. To make maximum use of the facility, cooperative studies with government, university, and other scientific laboratories in the Washington area are planned.

Waveguide Accelerates Pulsed Beam

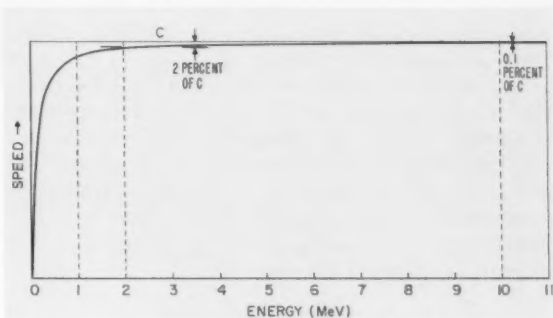
The NBS linac is basically a 100-ft pipe through which electrons are accelerated on the crest of a traveling radio-frequency wave. By using a moving field to accelerate the electrons, the linac achieves a high-energy electron beam without the need for excessively high voltages.

In a linac separate, individually powered accelerator sections which are coordinated as a unit are utilized to impart high energy to the electrons by means of repeated voltage applications. The NBS linac has nine accelerator sections through which pass the beam and the radio-frequency power that provides the acceleration voltage.

Since it is difficult to steadily maintain the high rf power necessary for an intense linac beam, the NBS linac beam is pulsed. Each electron pulse is synchronized with a burst of rf energy within the accelerator sections. The electron bunches within a pulse travel on the crests of the rf field as they move down the accelerator.

The beam ejected from the NBS linac is 3 mm in diameter and has an energy spread of less than 2 per cent (of full width at half maximum). Portions of this spectrum

Electrons entering the first accelerator section of the NBS linac quickly accelerate several MeV and thus travel at 99.9 percent of the speed of light (c) through the subsequent accelerator sections.



down to less than 0.1 percent can be selected by means of a system of magnets and apertures. Beam pulse widths may be varied from 0.1 to 6 microseconds at repetition rates up to 720 pulses per second. Table 1 outlines the beam characteristics.

Facility Designed for Flexibility

To provide radiation shielding, the entire linac facility has been constructed underground. It occupies a separate wing of the Bureau's new Radiation Physics Laboratory¹ at the Gaithersburg complex.

The linac facility has been designed so that the intense beam can be switched among three separate measurement rooms by the magnetic system. This feature greatly enhances the scope of research that can be undertaken with the machine since several experiments may be set up simultaneously even though the beam is utilized in only one room at a time. This arrangement also makes it possible for people to work in one measurement room while the linac beam is in use in another well-shielded measurement room. The measurement rooms have walls 12 to 17 feet thick and are entered through interlocking concrete horizontal-plug doors, each weighing 50 tons. It is planned also to bring the linac beam up to ground level, where time-of-flight paths up to one half mile are possible for a neutron time-of-flight program.

The linac wing occupies two basement levels 32 feet below the street level of the building. On the subbasement level are the linac chamber, the magnet room, and the measurement rooms. The linac cooling room, the power room, and the control rooms are on the basement level. Each measurement room is covered with 16 feet of earth. At all times, a specially designed ventilation system continuously replaces the air in the linac wing. A carbon dioxide fire control system also is installed throughout the wing.

continued

NBS LINEAR ACCELERATOR *continued*

On-Line Computer

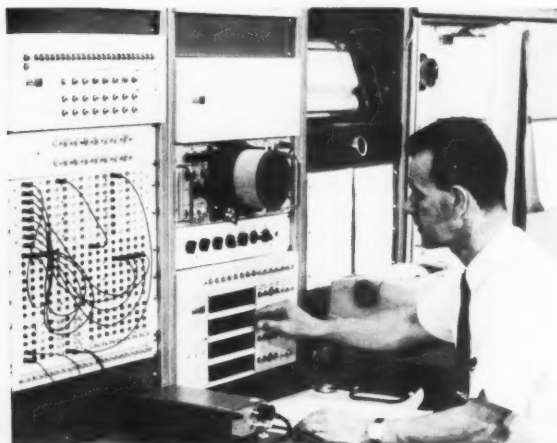
An unusually flexible and convenient computer system, specially developed at NBS for the linac, allows experimenters in the three measurement rooms to call for direct, "on-line" computer operations. By assigning a high priority level (there are 80 priority levels) to an operation that requires perhaps only a few hundred microseconds of computer time, it is possible to "steal" time from a program being processed by the computer at a low priority level. In each measurement room, data recording devices, many of which have been specially built at NBS, can convert a wide variety of input signals to a form directly acceptable to the computer.

Secondary Radiations

The NBS linac furnishes a beam of either electrons (e^-) or positrons (e^+). To obtain positrons, electrons accelerated by the first three sections of the linac are caused to strike a target and the resulting positrons are then accelerated by the last six sections. The intense beam (electrons or positrons) leaving the last section can in turn eject from a target a large number of secondary radiations for experimental work that are of sufficient intensity to be useful for additional target interactions.

A family of secondary radiations is readily obtainable in all the linac measurement rooms. The intensity of

NBS physicist James M. Wyckoff prepares to initiate a program previously loaded in the linac "on-line" computer. His request may interrupt other programs of lower priority, but may itself be interrupted when incoming signals of a higher priority are to be processed. The interrupt feature of the computer allows several experimenters, in the same interval of time, to call for short programs while the computer is processing a program or automatically recording other data.



the NBS linac beam, 9×10^{12} electrons per pulse, can produce 7×10^{11} neutrons per electron pulse or 3×10^5 rads per electron pulse. When the beam is used to produce photons from electrons, up to 600 rads per electron pulse result at one meter from the target.

Protective Measures

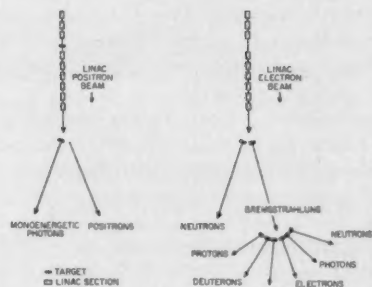
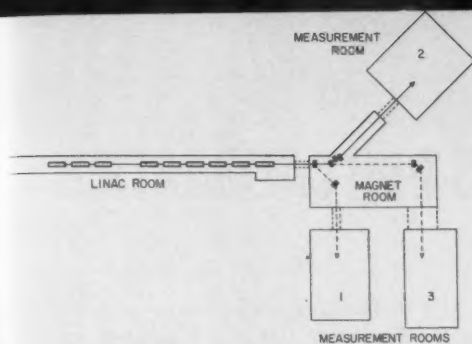
When the linac is to be placed in operation or the beam directed to a different measurement room, the entire area to be affected is inspected for personnel, according to a specific procedure. The inspector must press, in order, a series of buttons (usually 10), forcing him to take a certain complete route through the area. Failure to do this requires that he reinitiate the lock-up inspection. Prerecorded warnings of the imminent lethal radiation are broadcast throughout the linac wing of the building as soon as the lock-up inspection is initiated. After the final button is pressed, the inspector must leave the inspected area within 15 seconds; otherwise the linac will not operate within this area. At any time a person who feels he may be in a space that is unsafe can push an emergency button which completely shuts off all linac operations.

Linac Operation

Electron pulses are injected into the first accelerator section of the NBS linac by means of a 150-keV electron injector. Already traveling at a large fraction of the speed of light at injection, the electrons quickly accelerate several MeV in the first few feet of the section and attain a speed 99.9 percent that of light. The electrons then travel through the remainder of the first and the subsequent accelerator sections at almost constant speed (they never attain the speed of light) as the rf energy they absorb within each section now increases their mass but not their speed.

A number of precisely spaced iris diaphragms within each accelerator section form adjacent resonant cavities. As an rf burst enters a section, the wave interference pattern that propagates through the cavities results in moving points of high positive voltage (along the path through the iris-diaphragm centers) that are matched in speed with the electron-pulse speed. Successful coordination of a multi-section linac requires that a moving positive field and the electron pulse streak through each section together. The electrons thus absorb rf energy continuously as they travel within one section.

To obtain the maximum transfer of rf energy to the electrons in the linac, synchronization of the moving positive field and the electron pulse in the first linac section is critically important. It is, however, more difficult to achieve here than elsewhere since the electrons do not travel at constant velocity until they are part way through the section. Electron pulse injection must be very precisely timed with respect to the rf phase so that the electrons will be bunched at one of the crests of the rf field.



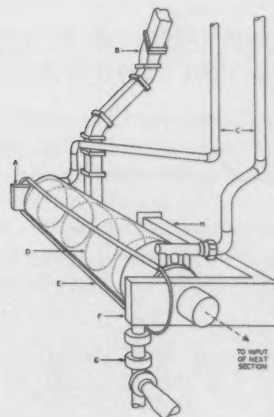
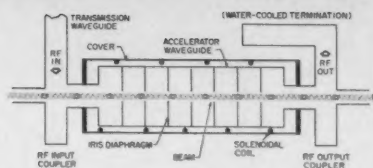
Top: Floor plan of the new linear accelerator installation which has been designed so that the intense electron beam can be steered from the magnet room among three measurement rooms (1, 2, and 3). The rooms are shielded from each other to permit work in one room while an adjacent room receives the beam or contains residual radioactivity. Bottom: Schematic diagram of the family of secondary radiations obtainable from the NBS linac electron (e^-) or positron (e^+) beam. Bremsstrahlung radiation, particularly can yield a variety of radiations.

Rf-energy bursts are furnished by 1300-MHz, 5-MW peak-power klystron tubes. The klystron tube units are located in the linac power room, one floor level above the linac. Rf energy from a unit travels down to the input coupler of one accelerator section by means of a transmission waveguide. The coupler feeds the rf energy into the accelerator waveguide, an 8.5-ft-long tube containing the iris diaphragms and situated inside the section's 10-ft-long cover tube.

At the end of the waveguide, an output rf coupler prevents unused rf power from entering the next section by feeding it into a water load that absorbs it. The electron beam continues straight to the next section. Only about one-half of the rf energy passing through a section is transferred to the beam; the rest is dissipated as heat.

The beam is positioned in the waveguide magnetically. A solenoidal coil, wound around the waveguide and carrying d-c current, confines the beam to a spot diameter of about 2 mm. Loops, mounted on the cover and carrying d-c current, correct any effects due to the earth's magnetic field and steer the beam.

The accelerator waveguide is evacuated and temperature controlled. The vacuum makes it possible to realize and



Top: Schematic diagram of an accelerator section of the NBS linac. Bottom: Line drawing of an NBS linac accelerator-section exterior. A, rf input coupler; B, transmission waveguide; C, water cooling pipes; D, solenoidal coil; E, beam steering loop (one of two, other below section); F, rf output coupler; G, a vacuum line; H, water-load rf termination.

maintain high rf field (by minimizing possible discharge paths due to the presence of ionized particles) and to maintain beam intensity (by keeping electron scatter by air molecules at a minimum). Water cooling pipes tied into each section maintain the temperature just underneath the cover at $110 \pm 0.1^\circ\text{F}$. Close temperature control keeps the critical spacing between the iris diaphragms constant.

Table 1
NBS LINAC BEAM CHARACTERISTICS

Energy	10-150 MeV
Power (average)	80 kW
Current (average)	0.6 mA
(Peak submicrosecond pulse)	2 A
(Peak 6 μs pulse)	0.3 A
Repetition rate	to 720 pps
Pulse length	0.01-6 μs
Energy spread (from linac)	2 percent FWHM ¹
(from magnetic system)	0.1 percent FWHM

¹ Full width at half maximum.

² Unique building houses radiation physics program, NBS Tech. News Bull. 50, 220 (Nov. 1966).

³ Memory size: 16,000 words; word length: 24 bits; cycle time: 8 sec/cycle. See On-line data handling system for the National Bureau of Standards LINAC, by J. E. Leiss, J. Broberg, R. Schrack, and J. M. Wychoff, IEEE Trans. Nuclear Sci. NS-11, No. 3, 331-337 (June 1964).



STANDARDS AND CALIBRATION

1966 CONFERENCE ON PRECISION ELECTROMAGNETIC MEASUREMENTS

The 1966 Conference on Precision Electromagnetic Measurements (CPEM), held at the Boulder (Colo.) Laboratories of the U.S. Department of Commerce June 21-24, has furthered coordination and cooperation in establishing international electromagnetic standards. It was jointly sponsored by the Radio Standards Laboratory of the National Bureau of Standards, the Group on Instrumentation and Measurement of the Institute of Electrical and Electronics Engineers, and the U.S. Commission on Radio Methods and Standards of the International Scientific Radio Union. It was also supported in part by the National Science Foundation and the Office of Naval Research.

The 1966 CPEM opened with a description by Dr. John M. Richardson, Chief of the Radio Standards Laboratory, of the worldwide system of physical measurements serving science and industry. He sketched the crucial part played by the great national standards laboratories of the world in keeping measurements valid and accurate, stating that the conference was an essential link between the developers and users of the system.

Dr. John T. Henderson of the National Research Council of Canada, General Chairman of the CPEM, emphasized the international aspect of the Conference and offered a special greeting to the many scientists from foreign countries. Dr. J. Terrien, Director of the International Bureau of Weights and Measures (BIPM) at Sèvres, France, the keynote speaker, related the history of international electrical units. He explained how the electrical standards of the BIPM are maintained and described the work of the BIPM in the field of electrical measurements.

At a later seminar on national measurement systems, Dr. Terrien emphasized that the BIPM is not only the physical center for international standards, but also the thinking center where scientists of the national laboratories exchange information and make decisions on the international level.

The foreign conferees and participants came from Canada, England, France, Israel, Italy, Japan, Sweden, Taiwan, and West Germany. Four were from industry, 22 from governmental administrative agencies, 4 from defense agencies, and 3 from universities. Of the 418 U.S. registrants, 182 were from industry, 22 from universities, 37 from the Department of Defense, 157 from civilian government agencies, 19 from private research laboratories, and 1 from the press.

The NBS Radio Standards Laboratory was not only the host for the Conference, but through its staff made many of the advance arrangements for the Conference and supplied 2 session chairmen. The 13 sessions covered 6 general areas: lasers, time and frequency, direct current and low frequency, microwaves, radiofrequency measurements, and precision connectors.

Of particular interest was a session devoted to descriptions, by a panel of representatives of the national standards laboratories of nine countries, of the nine national measurement systems they represented. Arranged and coordinated by Harvey W. Lance, Assistant Chief of RSL, it included presentations of the electrical standards of Australia, Canada, England, France, West Germany, Israel, Japan, Sweden, and the United States. This was followed by a discussion of the role to be played by the BIPM, which, although supported by 40-member nations, offers information and calibration services to both member and nonmember countries.

The multinational panel expressed the consensus that primary standards should be maintained by national standards laboratories and should be applied to as many user standards as the calibration facilities permit. The national laboratory should develop widely used standards and encourage special-interest organizations to develop and maintain standards of limited use. Conceivably, also countries might wish to specialize in the types of standards maintained, perhaps operating on a *pro tem* basis as an arm of the BIPM.

The papers presented at the 1966 Conference on Precision Electromagnetic Measurements will be published in the IEEE Transactions on Instrumentation and Measurement of December 1966.

The next such Conference is scheduled for June 25-27, 1968, also at the Department of Commerce Boulder Laboratories.

STANDARD FREQUENCY AND TIME BROADCASTS

WWV—2.5, 5.0, 10.0, 15.0, 20.0, and 25.0 MHz
WWVH—2.5, 5.0, 10.0, and 15.0 MHz
WWVB—60 kHz

Radio stations WWV (Fort Collins, Colo.) and WWVH (Maui, Hawaii) broadcast signals that are kept in close agreement with the UT2 scale by making step adjustments of 100 ms as necessary. Each pulse indicates that the earth has rotated approximately 15 arcseconds about its

axis since the previous one. Adjustments are made at 0000 UT (7:00 p.m., e.s.t.) on the first day of a month. There will be no adjustment made on 1 February 1967. The pulses occur at intervals that are longer than one second by 300 parts in 10^{10} due to an offset in carrier frequency coordinated by the Bureau International de l'Heure (BIH), Paris, France.

Radio station WWVB (Fort Collins, Colo.) broadcasts seconds pulses derived from the NBS Time Standard (NBS-III) with no offset. Step adjustments of 200 ms are made at 0000 UT on the first day of a month when necessary. The BIH announces when such adjustments should be made in the scale to maintain the seconds pulses within about 100 ms of UT2. There will be no adjustment made on 1 February 1967.

IMPROVED PROCEDURES PERMIT STAFF REDUCTION

Since early 1963, the Mass and Volume Section (Metrology Division, NBS Institute for Basic Standards) has reduced its staff from 40 full time members to the present total of 19. The reduction is a consequence of two major changes in operation.

VOLTAGE COMPARATOR *continued*

they are unenergized. The a-c input is selected only during the instant (from 50 to 100 μ sec) that one relay is energized and the other is in its unenergized position. The onset and end of the a-c sensing interval can be adjusted by delay controls to position the sensing interval at the peak of the sine wave.

The unknown a-c voltage is determined by adjusting the calibrated d-c reference to equal the a-c peak. When this adjustment is correctly made the same voltage is present throughout the sensing cycle, except for transitional intervals in relay operation. An opposing voltage is set to offset the comparison signal to near zero. The resulting composite signal is amplified and presented as vertical deflection by an oscilloscope. Use of high amplifier gain enables the comparison to be made with high precision; the value can be checked by shifting the sampling interval 180° along the input waveform and making the appropriate polarity reversal to obtain what should be a similar comparison.

Testing the Comparator

The NBS peak comparator was first checked against a commercial peak comparator of the resistance summing types; both received inputs of 10 V peak a-c and an adjustable d-c voltage. The d-c inputs sensed by each comparator as equal to the fixed a-c input were measured at spot frequencies of 50, 400, 1000, and 2400 Hz. Analy-

The first occurred in the calibration of volumetric glassware. For years the Section had performed thousands of such calibrations annually, the calibrated items being sold by the manufacturers mainly to the Food and Drug Administration. Now, as a result of cooperative arrangements with the FDA, the glassware manufacturers, and the General Services Administration, the number of items to be calibrated by NBS has been substantially reduced.

The second change involved calibration of mass standards. Here the Section initiated a Pilot Program designed to provide other laboratories with a more thorough knowledge of their own mass measurements than calibration alone could give. With NBS providing consultations, detailed weighing procedures, assistance in data reduction, and the calibration of two starting standards, the participating laboratories can maintain a running check on the quality of their measurements and the Section can significantly reduce its calibration workload.

Most of the personnel made available by these changes have been transferred to other positions in the Metrology Division where they were sorely needed.

sis showed that the d-c values assigned by the NBS comparator were in each case slightly higher than those assigned by the summing type comparator. The difference averaged 28 ppm (parts per million), or 0.0028 percent, with a maximum of 51 ppm for an individual run. This result signifies high reliability and precision in measurements made by the instrument.

The NBS peak comparator was then tested against the NBS thermal transfer standard and was found to have an ac-dc difference of less than 15 ppm for all test frequencies but 50 Hz. The poorer performance at 50 Hz is believed to be due to waveform deterioration in the a-c supply and in the input transformer at lower frequencies.

An evaluation of the data obtained from comparisons of the summing type comparator with the NBS comparator and with the NBS thermal transfer standard showed that the NBS comparator is capable of establishing the ac-dc transfer error of a peak comparator with unexplained discrepancies of 10 ppm or less.

¹ Calibration of peak a-c to d-c comparators, by D. Flach and L. Marzetta, Preprint No. 14.2-3-65, ISA Conference (Oct. 5, 1965, Los Angeles, Calif.), and

A Peak AC-DC Voltage Comparator for Use in a Standards Laboratory, NBS Tech. Note 280, by L. Marzetta, available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, at a cost of 25 cents.

² For further information on rms voltage measurements, see A-c voltage calibrations, NBS Tech. News Bull. 47, No. 8, 132-135 (Aug. 1963).

³ A system for accurate d-c and a-c voltage measurements, by F. L. Hermach, J. E. Griffin, and E. S. Williams, IEEE Trans. Inst. & Meas. IM-14, 215-224 (Dec. 1965).



NEWS

This column regularly reports significant developments in the program of the National Standard Reference Data System. The NSRDS was established in 1963 by the President's Office of Science and Technology to make critically evaluated data in the physical sciences available to science and technology on a national basis. The System is administered and coordinated by the National Bureau of Standards through the NBS Office of Standard Reference Data, located in the Administration Building at the NBS Gaithersburg Laboratories.

International Cooperation in Standard Reference Data Activity

With the establishment of the NBS Office of Standard Reference Data, increased interest has developed internationally in data compilation programs. Some of the activities that have resulted from this interest are reviewed in the following paragraphs.

ICSU Organizes CODATA

Recognizing that the compilation of critical tables of reference data is an international problem, the International Council of Scientific Unions (ICSU) has established a Committee on Data for Science and Technology (CODATA). The new committee will stimulate awareness of the many aspects of the problem and will promote communication and voluntary coordination among compilers in all countries to achieve optimum utilization of manpower and financial resources.

The ICSU is the coordinating body for 15 international unions representing major areas of science. About 60 countries participate in the ICSU through their national academies or other national interdisciplinary scientific bodies. Formerly the ICSU was the International Research Council which co-sponsored the *International Critical Tables* in 1922.

CODATA will have representation from 12 international unions and 6 countries. The unions are those active in the fields of astronomy, biological sciences, crystallography, geodesy and geophysics, geography, geological sciences, physiological sciences, pure and applied biophysics, pure and applied chemistry, pure and applied physics, scientific radio, and theoretical and applied me-

chanics. The 6 countries and their representatives on CODATA are: France, Prof. B. Vodar; West Germany, Prof. Dr. W. Klemm; Japan, Prof. Dr. M. Kotani; U.K., Sir Gordon Sutherland; U.S.A., Prof. F. D. Rossini; and U.S.S.R., Academician M. A. Styrikovich.

The program formulated by CODATA will be carried out by a permanently staffed Central Office, which will be financed by participating countries. For the first 2 years, the Office will be located at the National Academy of Sciences in Washington and will then move to Western Europe.

Among the tasks which CODATA has set for itself are: (1) to ascertain through its members (a) what work on critical compilation of evaluated numerical data is being carried on in each country; (b) what work is being sponsored by each Scientific Union or by other international groups; and (c) what the needs of science and industry are for additional compilations of evaluated data; (2) to achieve coordination among, and strengthening of, existing programs in such a way as to maximize their effectiveness, to minimize unintentional or undesirable overlap, and to recommend new compilation programs when necessary; and (3) to encourage the support of needed work by appropriate private, governmental, and intergovernmental agencies; and to encourage experimental work.

To aid the Central Office in generating information and providing communications with unions and with countries, it is expected that many of the national and union representatives on CODATA will seek to organize appropriate advisory groups in their countries or unions. For example, both the U.K. and the U.S.A. have formally organized National Committees for CODATA, within the Royal Society and National Academy of Sciences, respectively. Such committees will increase awareness in many disciplines of the need for strong programs for preparing reference data. These committees will also serve as sources of information and advice for governmental or non-governmental groups within particular countries.

The Central Office expects to be fully staffed by early 1967. During the 2 years that the CODATA Office is in Washington, Dr. Guy Waddington will serve as its Executive Director; he will also continue as Director of the Office of Critical Tables.

A State System of Standard Reference Data in the U.S.S.R.

Reasoning similar to that which led to the establishment of NSRDS in the United States has led the Soviet Union to organize a State System of Standard Reference Data:

"... necessary planning and system are lacking in obtaining the enormous aggregate of reliable and authentic data on the physicochemical properties of materials and substances. The existing conditions with respect to reference data about the properties of materials result in a very large economic loss to the State, despite the fact that all over the Union large sums of money are being spent on testing materials and evaluating their characteristics. None of this work is part of a common plan, the data obtained in the large number of institutions and laboratories of our country are not systematized, the values thus obtained are of an advisory nature and, therefore, cannot be taken as the basis for reliable computations without special, more-or-less exhaustive checking . . . the most important reasons for this condition . . . are:

- the lack of coordination and planning . . .
- insufficient metrological analysis and critical evaluation of data . . .
- lack of legalization or official sanctions for the published data . . .
- lack of a system for storing and processing information, and an organized state publication of reference data . . .
- lack of unified, standardized test methods and approved, standard equipment for testing."

The U.S.S.R. equivalent of the U.S.'s NSRDS calls for an authoritative scientific program management office which would:

1. Draw up a list of standard reference data requirements, establish priorities, develop a program of fields of data to be pursued, and design a system for the storage, publication, and documentation of the accumulated data.
2. Locate and establish competent scientific organizations to test, compile, and evaluate the standard reference data.
3. Define and establish a technical scope for the physicochemical properties of the program.
4. Establish unified standards of testing and evaluation as well as engineering standards.
5. Establish a scientific information center within the program for accumulating, classifying, and storing standard reference data and for answering queries.²

The U.S.S.R. blueprint is quite similar to NSRDS in objectives and design. A major difference, however, is that the Soviet State Agency also has the responsibility for establishing standards for engineering materials; NSRDS is concerned only with the physical and chemical properties of pure and/or clearly definable substances.

Directory of USAEC Specialized Information and Data Centers

The U.S. Atomic Energy Commission has issued a directory³ of the 26 information and data centers it supports fully or partially. Most of the centers are at AEC laboratories, but some are at universities. The directory includes the name, address, and telephone number of the director of each center, as well as information on sponsorship details, year started, scope, a listing of services, staffing, and qualifications for users. Although many of the services are restricted to U.S. Government agencies and their contractors, many of the centers have services available to everyone.

Criteria for Identifying Data and Information Centers

The office of Standard Reference Data supports about 60 data activities, some of these are organized as, and formally called, centers; others are not. This Office has been attempting to clarify and establish working criteria to identify those activities that may be classified as centers using the following definitions.

Data: Quantitative information on the physical or chemical properties of substances or systems of substances.

Standard Reference Data: Critically evaluated quantitative information relating to a physical or chemical property of a definable substance or system.

Data Compilation: A collection of quantitative information with a significant internal relationship among the items of the collection, as well as validity for the items as separate units of information.

Information: Knowledge of a factual kind, usually gathered from others, or from any of the various storage media, made available for communication or use.

Data Center: An information organization specializing in handling and evaluating numerical information for a specific field.

Information Center: An organization which analyzes, synthesizes, and/or evaluates and repackages the contents of documents for the purpose of enabling users to better assimilate the information of a specific field.

Document Center: An organization acquiring, announcing, abstracting, indexing, distributing, and selectively disseminating documents in response to requests for content.

There may be some confusion about the differences between data and information centers. Within their specific missions, information centers are less restrictive and more encompassing in their approach to services and users. They may or may not produce compilations of numerical information; they may also furnish information about theory, instrumentation, applications, or other aspects of the fields they cover. Data centers are concerned essentially with the production of quantitative data; they are more restrictive in their approach to services and

continued

NSRDS NEWS *continued*

users, limiting their purview to data and ancillary publications.

In general, the programs of information and data centers consist of some or all of the following activities:

- 1) Literature scanning and selection
 - 2) Literature indexing
 - 3) Abstract preparation
 - 4) Bibliography preparation
 - 5) Preparation of technical status summaries
 - 6) Preparation of uncritical data compilations
 - 7) Preparation of critical data evaluations and compilations
 - 8) Preparation of critical status reviews
 - 9) Computation of useful functions derived from critically evaluated data
 - 10) Providing information services to users for any of the above items
 - 11) Providing answers to technical questions
 - 12) Issuing ad hoc and/or serial publications—newsletters, abstracts, journals (as well as compilations, and state-of-the-art critical reviews)
 - 13) Disseminating any or all of the above mentioned products to specific members of the technical community or to any one interested in receiving them.
- Not all activities producing standard reference data should be classified as centers. The following may be considered criteria for a center supported by the Office of Standard Reference Data: The center should have (1) a specific technical mission and plans for a long-term, continuous operation for the coverage of a specific field; (2) The

center should have an explicit, articulated plan for relating its mission to its specific users' requirements; (3) The center should be comprehensive within the scope of its mission; and (4) It should offer a variety of products and services and perform a significant portion, though not necessarily all, of the range of services identified in the 13 categories above. In addition, a center should have (5) a carefully selected, competent staff:

- a. Supervision—the operation should be supervised by a recognized expert in the field.
- b. Professional staff—all matters requiring exercise of critical judgment should be handled by persons of adequate skill and sophistication.

Among the tasks of NSRDS-associated centers producing standard reference data are (1) Literature survey—examining the literature to determine and select relevant material; (2) An indexing operation—identifying what has been selected; (3) Extracting operation—extracting the data and all relevant background material to provide the evaluator with enough information on the value of the literature under analysis; (4) Critical evaluation—the production of compilations of critically evaluated data.

The non-center project, on the other hand, is set up for an *ad hoc* task or set of tasks, designed to accomplish a particular purpose; such as a data compilation, critical review, or bibliography; the production of which completes the project.

¹ The system was described in the Soviet journal, *Izmeritel'naya Tekhnika* (Measurement Techniques), of May 5, 1964. The translation was sponsored by the Instrument Society of America under a grant from the National Science Foundation with additional assistance from the National Bureau of Standards.

² *Ibid.*

³ Available from the Division of Technical Information, U.S. Atomic Energy Commission, Washington, D.C. 20545.

PUBLICATIONS *of the National Bureau of Standards**

PERIODICALS

Technical News Bulletin, Volume 50, No. 12, December 1966. 15 cents. Annual subscription: \$1.50. 75 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

Journal of Research of the National Bureau of Standards

Section A. *Physics and Chemistry*. Issued six times a year. Annual subscription: Domestic, \$5; foreign, \$6. Single copy, \$1.

Section B. *Mathematics and Mathematical Physics*. Issued quarterly. Annual subscriptions: Domestic, \$2.25; foreign, \$2.75. Single copy, 75 cents.

Section C. *Engineering and Instrumentation*. Issued quarterly. Annual subscription: Domestic, \$2.75; foreign, \$3.50. Single copy, 75 cents.

CURRENT ISSUES OF THE JOURNAL OF RESEARCH

J. Res. NBS 71A (Phys. and Chem.), No. 1 (Jan.-Feb. 1967), \$1. Dedication of the new NBS laboratories.

Electric fields produced in cubic crystals by point defects. A. D. Franklin and D. J. Sparks.

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Dissociation constant of m-nitrophenol in 50 wt percent methanol-water solvent from 25 to 40 °C and related medium effects. B. J. Steel, R. A. Robinson, and R. G. Bates.

On the calculation of moments of molecular weight distribution from sedimentation equilibrium data. I. H. Billick, M. Schulz and G. H. Weiss.

The far infrared spectrum of vulcanized natural rubber. J. E. Stewart and F. J. Linnig.

Irradiation of dextran and its aqueous solutions with cobalt-60 gamma rays. J. H. Flynn, L. A. Wall, and W. L. Morrow.

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Large-scale, preparative paper chromatography. H. L. Frush.

Infrared absorption spectra of some aldofuranoid, aldopyranoid, and acyclic 1-acylamido derivatives of sugars. R. S. Tipson, A. S. Cerezo, V. Deulofeu, and A. Cohen.

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January

- Alcissas and weights for Gaussian quadrature for N-2 to 100, and N-125, 150, 175, and 200. C. H. Love.
- Transverse impact of a linear three-element spring and dashpot model filament: theory. J. C. Smith.
- Functions for thermal stress calculation near a transient heat source on a flat surface. S. Jarvis, Jr., and G. Hardy.

OTHER NBS PUBLICATIONS

- Standard Reference Materials: Determination of oxygen in ferrous materials SRM 1090, 1091, and 1092, O. Menis and J. T. Sterling. Misc. Publ. 260-14 (Sept. 23, 1966), 30 cents.
- Hydraulic research in the United States 1966, Ed. H. K. Middleton and G. Kulin. Misc. Publ. 280 (Sept. 8, 1966), \$1.50.
- High temperature properties and decomposition of inorganic salts. Part 1. Sulfates, K. H. Stern and E. L. Weise, NSRDS-NBS7 (Oct. 1, 1966), 35 cents.
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